

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION OF

Esa Malkamäki, Deepak Mathew, Kari Pehkonen

and

Jussi Kähtävä

FOR

**METHOD OF SENDING FEEDBACK INFORMATION IN A FAST
AUTOMATIC REPEAT REQUEST FORMING PART OF AN OVERALL
WIRELESS COMMUNICATION SYSTEM**

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Technical Field:

The present invention relates to sending feedback data to a sender of packets in a wireless communication system and in particular is directed to a new feedback channel for use in fast hybrid automatic repeat request.

Background of the Invention:

Fast hybrid automatic repeat request (HARQ) has been proposed as a vehicle to solve receiver memory problems which occur when soft combining schemes are used in wireless communications. The fast HARQ requires that an acknowledgement (or the so-called forward order) be transmitted within the next radio frame after the transmission of packet(s) in the forward direction. Hybrid ARQ (HARQ) is a link adaption technique used to improve the performance of wireless communications. In a Type 1 Hybrid ARQ, there is soft combining which is a type of repetition coding in which the retransmitted packet is combined with the initially transmitted packet. In Type 2 Hybrid ARQ, an incremental redundancy scheme is used. In both Type 1 and Type 2 Hybrid ARQ, the soft decision values of the erroneous packet, if detected, must be stored in the receiver which in turn can lead to very high memory requirements at the receiver. Thus the amount of memory required for storing these soft decisions is proportional to the retransmission time interval. Fast hybrid ARQ has been proposed to decrease retransmission delay which in turn decreases the memory requirements at the receiver.

In prior art schemes, the whole ARQ protocol is in the radio link control (RLC) layer and the feedback data as well as the retransmissions have been generated in the RLC layer as described in the Release 1999 3GPP specifications. This type of feedback data is not suitable for fast HARQ if the RLC in the network side is located in the radio network controller (RNC) since the Iub interface between RNC and Node B (the base station) can cause long delays. The delay of the Iub interface is one of the main reasons for the long round trip delays. This prior art technique requires that the retransmission delay becomes very high (typically from approximately ten to twenty

transmissions in time intervals (TTIs). This retransmission delay therefore implies that the memory requirements at the transmitter, but especially in the receiver, must be very high in order to be able to retransmit and soft combine the retransmitted packets with the stored packets which were received erroneously.

One way to speed up the whole process is to generate the feedback data in the physical layer of the receiver. Similarly, the retransmissions should be generated at the physical layer of the transmitter. Alternatively, the feedback and the retransmission can also be generated in a layer which is co-located with the physical layer, thereby eliminating any long delay between these two layers.

There are several ways of transmitting the feedback data. One possibility is to transmit it through existing uplink or downlink channel. This has the problem that the existing channels are usually terminated in the radio network controller (RNC) in the network side, i.e., there is the delay between the base station and the RNC. Even if the termination of the existing transport channel were changed to a base station in the network side, the transmission delay would be at least three TTIs more than that of the proposed invention since the existing transport channels are interleaved at least over ten milliseconds (ms) (see 3GPP spec).

All the previous implies that a separate fast feedback channel needs to be defined. One straightforward possibility in a CDMA system is to transmit the feedback data using a separate code channel and transmit it in parallel with other data which has been proposed for instance by Motorola Corporation for its one XTREME system. This requires multi-code transmission which is not desirable in the mobile terminal (if the feedback is in the uplink direction).

Summary of the Invention:

The present invention provides a solution for fast feedback associated with fast HARQ and thereby solves the buffering problem associated with other feedback mechanisms. In particular, the technique of the present invention does not require the use of a separate code channel for feedback information

but rather is able to steal some of the capacity from uplink traffic data or control traffic (or downlink traffic depending upon the direction of the packets) in order to provide the necessary feedback data. In another embodiment of the invention, dedicated physical control channel (DPCCH) bits are used for the fast feedback. The method according to the present invention is described with respect to the downlink transmission of a frequency division duplex (FDD) as an example. Thus the feedback is in the uplink direction. Of course, extension of this description to uplink data is straight-forward, wherein the feedback would be in the downlink direction.

Hybrid ARQ is a link adaption technique which is used to improve the performance of wireless communication systems and the Type 1 Hybrid ARQ with soft combining uses a type of repetition coding in which the retransmitted packet is combined with the initially transmitted packet. Type 2 Hybrid ARQ uses an incremental redundancy scheme and thus both in Type 1 and Type 2 Hybrid ARQ soft combining is utilized in the receiver and soft decisions values of the erroneous packets have to be stored in the receiver which of course, can lead to very high memory requirements at the receiver. It is thus clear that the amount of memory required for storing the soft decisions is proportional to the retransmission time interval.

For wireless communication system, the uplink and downlink radio frames have a probable time displacement between the uplink and downlink channels. For dedicated channels, the uplink and downlink frames are typically separated by 1,024 chips. The purpose of the fast feedback is to reduce the time interval for transmitting the feedback after receiving the packet. However, the receiver must typically de-interleave, de-ratematch, decode and error check the received packets after reception of the radio frame and all of these operations require time. Thus the fastest way to send acknowledgement is to stuff the feedback data in the next frame in the uplink direction so that the transmitter can retransmit the erroneous packets with a delay of only one transmission timing interval (TTI).

The present invention achieves this goal by reserving a few slots, fully or partly, where the number of slots can be a parameter, in the uplink

Dedicated Physical Data Channel (DPDCH) radio frame for feedback data only. This technique implies that data in the uplink direction can be transmitted only in the remaining slots (also in the remaining parts of the slots if the slots are only partly used for feedback). The feedback data is transmitted in slots N_1 to $N_2 - 1$ and the data in the uplink direction are therefore transmitted in slots 1 to $N_1 - 1$ and in slots N_2 to N , where N is the number of slots in a radio frame. In this technique, the value of N_1 is dependent upon the time offset between the uplink and downlink channels. It is also dependent upon the time required for any de-interleaving, de-

ratematching, decoding and error checking at the receiver. Furthermore, the number of feedback slots (N_{fb}) depends on the size of the feedback packet. If forward ordering is used, the value of N_{fb} is typically three or four slots.

An alternative implementation of the fast feedback channel can use some of the dedicated physical control channel (DPCCH) bits in the given slots. Thus feedback bits can be punctured into the pilot, transmit power control (TPC) bits, transport format combination indicator (TFCI) bits and feedback information (FBI) bits of one or several time slots. Alternatively, the feedback information can be time multiplexed with the existing pilot, TPC, TFCI and FBI bits by, for example, changing the spreading factor of the DPCCH so that more channel bits will be available.

Brief Description of the Drawings:

For a fuller understanding of the nature and object of the present invention, reference should be made to the following detailed description, taken in conjunction with the following drawings, in which:

Figure 1 is an illustration of a plurality of downlink and uplink radio frames associated with a wireless communication system, wherein each frame comprises a plurality of slots.

Figure 2 is an illustration of a radio frame with associated slots numbered one through fifteen and showing the usage of

some of those slots for the presentation of feedback data according to the present invention.

Figure 3 is a flow chart showing how rate matching and interleaving are combined with feedback data by a slot multiplexer.

Figure 4 is an illustration of an uplink radio slot and how the dedicated physical control channel (DPCCH) bits can be used to provide feedback data.

Best Mode for Carrying Out the Invention:

As best seen in Figure 1, wireless communication systems typically communicate from a sender to a receiver via uplink and downlink frames 10 and 12, wherein each frame comprises a plurality of slots 14. For a typical frame, the number slots is fifteen. Typically there is a time displacement between the uplink and downlink channels. For dedicated channels, the uplink and downlink frames are separated typically by 1,024 chips.

As presented herein, the methodology is described with reference to downlink transmission of frequency division duplex (FDD) wireless communications in which the feedback for such communications is presented in the uplink direction. It will be noted to anyone of ordinary skill in the art that extension to uplink data in which the feedback is presented in the downlink direction is a straight-forward extension of this description and forms part of the present invention.

In the development of wireless communications, the concept of automatic repeat requests has been adopted to allow for the receiver of packets to request that any packet be retransmitted if it was not properly received. Of course, this implies that the sender of such a packet must store that information for possible retransmission until such time that the sender receives acknowledgement from the receiver that the packet has been received properly. The longer the time delay between sending the original packet and receiving the acknowledgement, the longer the sender must store that packet for possible retransmission in the event that it is not properly received by the receiver.

Faced with this problem and the associated expense and complexity of large storage, techniques have been adopted which have modified the original automatic repeat request concept in what is now known as hybrid ARQ (sometimes referred to as HARQ). Hybrid ARQ is a link adaptation technique which is used to improve the performance of wireless communication systems. In what is known as Type 1 hybrid ARQ, there is soft combining where a type of repetition coding is performed in which the retransmitted packet is combined with the initially transmitted packet.

In what is known as Type 2 hybrid ARQ, an incremental redundancy scheme is used. For both Type 1 hybrid ARQ with soft combining, as well as Type 2 hybrid ARQ, the soft decision values of the erroneous packet have to be stored in the receiver which can lead to very high memory requirements at the receiver. It is therefore clear that the amount of memory required for storing the soft decisions is proportional to the retransmission time interval. Fast physical layer hybrid ARQ has been proposed to decrease the retransmission delay which in turn decreases the memory requirements at the receiver.

The present invention describes a fast feedback scheme for a fast physical layer hybrid ARQ for data transmitted in the downlink direction. The invention equally applies to where the data is transmitted uplink direction (feedback in the downlink direction). The purpose of fast feedback is to reduce the time interval for transmitting the feedback after receiving the packet. Upon receiving a packet, a receiver typically performs de-interleaving, de-rate matching, decoding and error detection of the packets in the radio frame and these operations require a finite amount of time to perform. Thus the fastest way to send acknowledgement to the sender of the frame is to send the feedback data in the next frame in the uplink direction as shown by slot 14 within each of the uplink frames. With this method, the transmitter can retransmit any erroneous packets with the delay of only one transmission timing interval (TTI).

As best seen in Figure 2, a practical way to achieve this result is to reserve a few slots (where the number of slots can be a parameter) in the

uplink Dedicated Physical Data CHannel (DPDCH) radio frame for use as feedback data alone. The number of feedback slots (N_{fb}) typically can range in size from two to four slots and resides specifically in slots N_1 to $N_2 - 1$. Thus N_{fb} is equal to $N_2 - N_1$. Other data transmitted in the uplink direction is therefore transmitted in slots 1 to $N_1 - 1$ and in slots N_2 to 15, where 15 slots form a typical radio frame, (that is, where $N = 15$).

The value of N_1 depends on the time offset between the uplink channel and the downlink channel, as well as dependent upon the time required to perform de-interleaving, de-ratematching, decoding and error checking (typically cyclical redundancy checking). The value of N_{fb} depends on the size of the feedback packet and if forward ordering is used, the value of N_{fb} is typically three or four slots.

If the uplink and downlink radio frames are time aligned as shown in Figure 1, then a typical value for N_1 is 8 and N_2 can be 9, 10, 11 or 12, depending upon the size of the feedback packet (that is N_{fb} can be 1, 2, 3 or 4 slots respectively).

During initial call setup phase, the user equipment (UE) and the network agree upon a suitable size for N_1 and N_2 . The network and ratematching unit 20 (see Figure 3) ensure that the uplink data can be accommodated in $15 - N_{fb}$ slots. The slot multiplexer 22 multiplex the uplink data as well as the feedback packets 24 into the proper slots.

The space or gap for the feedback channel can be generated in the same way as that used for compressed mode, that is by puncturing or by higher layer scheduling. The latter technique is usually more appropriate since the needs for the feedback channel are known beforehand and can be taken into account when defining transport format combinations.

The feedback slot(s) N_{fb} need not necessarily be transmitted during the next radio frame. The feedback can be delayed due to processing delays so as to be presented in a later frame with an associated known offset between the data channel and the feedback channel. However, the feedback channel would itself be implemented in the same manner as described above.

The feedback slots may use the same or a different spreading factor (SF) as the other data. The reason for a different SF can be, for instance, the desire to use a fixed SF for the feedback channel regardless of the SF used for other data. A fixed SF for the fast feedback channel can simplify the reception of the fast feedback channel if a separate receiver is used for the fast feedback channel. A fixed SF for the fast feedback channel can be implemented by repeating the fast feedback bits n times if the SF of the feedback channel is n times larger than the SF of the data channel. If, on the other hand, the same receiver is used for both data and feedback, then the same SF is desirable for both feedback and other data.

Alternative Embodiment

As best seen in Figure 4, an alternative implementation of the fast feedback channel can make use of bits in the dedicated physical control channel (DPCCH) 26 in the given slots of the radio frame. An uplink radio frame is shown in Figure 4. Region 28 is the portion of the DPCCH channel where signalling bits are punctured for use as feedback. Feedback bits can be punctured into the pilot, feedback (FBI) or transmit power control (TPC) fields of one or several time slots. Figure 4 shows feedback bits punctured into the pilot field of uplink DPCCH. Downlink DPCCH can be punctured in a similar fashion. If more than only a few feedback bits are needed, the spreading factor (SF) of the DPCCH can be reduced, thus creating more bits per time slot. The signalling information can then be mapped to some of the uplink slots and there would still be room for pilot, transport format combination indicator (TFCI), FBI and TPC bits. Feedback information can also be encoded within the TFCI field if the number of transport format combinations needed during the connection leaves part or whole of the TFCI field unused. The dedicated physical data channel DPDCH 30 is also shown in Figure 4.

In addition, the present invention can be use for a time division duplex as well as frequency division duplex communication format. For time division duplex, the data is normally transmitted in given slots thereby forming bursts. The use of fast feedback requires that the proper slot (with a given offset to the

other data channel) be allocated for that user. The feedback channel can use a part of the capacity of the burst or the entire burst. Once the required slot is allocated, ratematching can be used to introduce the gap needed for the fast feedback channel and the feedback bits can be added after second interleaving. That is, they can be added before the second interleaving if time slot related second interleaving is used.

In general, the methodology of the present invention can be used for any feedback signalling, especially if the timing requires the use of a certain position within the frame for such signalling. For instance, fast cell site selection can use similar feedback signalling methodology.

Thus what has been described is a method of sending feedback information in a fast automatic repeat request in which received packets are acknowledged by transmitting feedback data to the sender of the packets, wherein the acknowledgement comprises the reservation of a plurality of slots in the uplink dedicated channel radio frame for the feedback data alone. It is also directed to a method of providing fast feedback in which dedicated physical control panel (DPCCH) bits are used in at least some of the slots for transmitting the feedback data to the sender.